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14. ABSTRACT
This research has lead to three very interesting and important learnings:
1. We were able to develop computational techniques to measure the theoretical optimal performance in both the spatial navigation with uncertainty task and the Seek-And-Destroy task.
a. This lead to the development of a hand-held indoor navigation aid that is completely self-contained (Stankiewicz, Cassandra, McCabe & Weathers, 2007).
2. We found that individuals were sub-optimal in their ability to make decisions with uncertainty. We were able to localize the sub-optimal behavior to the inability to correctly calculate the likelihoods of the current true state.
3. We were able to provide users with a decision making aid that brought their decision making efficiency.

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Navigation and Decision Making Efficiencies under Conditions of Uncertainty.

FA9550-04-1-0236

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Each and every day we make thousands of decisions in which our understanding of the situation is not completely known. Although we may have incomplete knowledge, we may possess knowledge that will be helpful in making a "good" decision. For example, when purchasing an automobile, one does not know for certain how reliable *this* car will be. However, given the make and model's previous track record, one might be able to generate an initial estimate its reliability. However, given that the car is used, there is some uncertainty about how well the car was maintained and how it was used. One may consider purchasing an inspection by a mechanic. Following the inspection, one might be more confident that the car will be reliable—however, even with this additional information one is still in a state of uncertainty. One may consider purchasing an additional inspection to reduce one's uncertainty even more. As one can see, an individual can continue to gather more-and-more information at a greater and greater accumulated cost. However, this additional information comes at a cost that may not exceed the expected gain in knowledge.

The research in this program was interested in four questions related to our ability to make decisions with uncertainty. First, computationally, what is the optimal decision strategy? To this end we used a Bayesian model of sequential decision making with uncertainty called **Partially Observable Markov Decision Processes** (POMDP). This model provides us with the theoretically optimal performance in a sequential decision making with uncertainty task. Second, we were interested in characterizing human sequential decision making with uncertainty. Specifically, we were interested in understanding how well humans performed relative to the optimal decision maker. This performance gave us a measure of human decision making efficiency. Third, if we found that humans were not making decisions optimally, we were interested in understanding what sub-process might lead to this inefficient behavior. Finally, if people were sub-optimal in their decision making process, we were interested in understanding whether we could develop decision aids that would allow human decision making to become optimal, or near optimal.

To address these issues we studied human spatial navigation when individuals were "lost" within a familiar environment and also a "Seek-And-Destroy" task in which the decision maker had to locate and destroy a target. In the S&D task, the decision maker needed to locate the target using "reconnaissance" that would indicate whether the target was observed or not. However, the reconnaissance was not perfect in that some times it would detect the target at a location, but the target was not located there (false alarm) or the reconnaissance would not detect the target but it was at that location (miss). Furthermore, the decision maker could send artillery to a location and if the target was there, some times it would miss. Furthermore, each of these actions (reconnaissance and artillery) had a cost associated with them. The decision maker’s task (both human and computational model) was to destroy the target and Declare that the target was destroyed. If the decision maker successfully destroyed the target when they declared they received a positive reward, but if they declared and the enemy was still alive, the decision maker received a large negative reward.

This research has lead to three very interesting and important learnings:

1. We were able to develop computational techniques to measure the theoretical optimal performance in both the spatial navigation with uncertainty task and the Seek-And-Destroy task.

    a. This lead to the development of a hand-held indoor navigation aid that is completely self-contained (Stankiewicz, Cassandra, McCabe & Weathers, 2007).

2. We found that individuals were sub-optimal in their ability to make decisions with uncertainty. We were able to localize the sub-optimal behavior to the inability to correctly calculate the likelihoods of the current true state.

3. We were able to provide users with a decision making aid that brought their decision making efficiency (the human performance relative to the optimal performance) from about 50% to nearly 90%.

<u>Summary:</u>

In summary, we have brought together the power of computation by developing a computational model of sequential decision making with uncertainty along with understanding the strengths and limits of human decision making. In fact, one of the most remarkable findings in this research program was that there is an interesting symbiotic relationship between the human and the computer in sequential decision making. The decision process in sequential decision making can be broken down into two sub-tasks. The first is integrating the new piece of knowledge that was acquired to update the likelihoods of the current "true state" (e.g., the likelihood that the target is at one location or another). The second, is given these likelihoods, what is the best action to enact at this time. For the computer, the first process is quite simple and on a typical contemporary computer can be completed in less than a second. For many problems (including those that were studied in this research project) computing the best action given the likelihoods can take hours, days or weeks. However, the human has the opposite problem. We have difficulties updating the likelihoods of the true state, but given these likelihoods (e.g., when computed by the computer) our research has shown that we can make near optimal decisions on which action to engage in next. This research suggests that a very important cognitive aid for human sequential decision making is one that updated the likelihoods when new information is received.

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University of Illinois at Urbana-Champaign, February
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